Review of Carbon TerraVault (CTV) Responses to EPA's Questions about Operating Procedures for the A1-A2 Project

In January 2022, EPA provided questions to CTV (*blue, italic text*) about the proposed operating procedures for injection wells 355-7R and 357-7R submitted as part of CTV's Class VI permit application (dated August 30, 2021 and December 2, 2021) for the proposed Carbon TerraVault (CTV)-Elk Hills Class VI geologic sequestration (GS) project. CTV provided updated operating procedures for the two wells to EPA on March 31, 2022. EPA's evaluation of how the update addresses its questions is presented in red below. Requests for revisions and additional information are presented in ***red, bold, and italic*** below. Previous responses that require no further information are not included in this enclosure.

The proposed operational procedures (which appear to be specific to Well 357-7R) are described on page 47 of the initial Narrative and summarized in Table 8, which is replicated below:

Table 8 of initial Narrative (for Well 357-7R)		
Parameters/Conditions	**Limit or Permitted Value**	**Unit**
Maximum Injection Pressure		
Surface	3,800	Psig
Downhole	6,100	Psig
Average Injection Pressure		
Surface	1,600	Psig
Downhole	4,100	Psig
Maximum Injection Rate	30 per well	Mmscfd
Average Injection Rate	10-15 per well	Mmscfd
Maximum Injection Volume and/or Mass	10 Million	Tonnes
Average Injection Volume and/or Mass	8 Million	Tonnes
Annulus Pressure	3,730 @ packer	Psig
Annulus Pressure/Tubing Differential	370@packer @ average injection condition	Psig

The proposed operational procedures for Well 355-7R are described in the amended Narrative (Attachment A2) and summarized in a revised Table 8, which is replicated below:

Table 8 of updated Narrative (for Well 355-7R)		
Parameters/Conditions	**Limit or Permitted Value**	**Unit**
Maximum Injection Pressure		
Surface	2,900	Psig
Downhole	6,108	Psig
Injection Pressure		
Surface Average / Maximum	1,400/1,600	Psig
Downhole Average / Maximum	4,300 / 4,516	Psig
Maximum Injection Rate	30 per well	Mmscfd
Average Injection Rate	10-15 per well	Mmscfd
Maximum Injection Volume and/or Mass	10 Million	Tonnes
Average Injection Volume and/or Mass	8 Million	Tonnes
Annulus Pressure	3,720 @ packer	Psig
Annulus Pressure/Tubing Differential	578@packer @ average injection condition	Psig

Injection Pressure

The basis for the proposed maximum injection pressure (MAIP) is described in Attachment B – the AoR and Corrective Action Plan (AoR CA). CTV states that the MAIP will be below 90% of the fracture pressure of the Monterey Formation at the base of the Reef Ridge Shale confining zone, and is calculated as follows:

$$8{,}150psi \times 0.9psi/ft = 7{,}335\ psi$$

Where:

Fracture pressure (Fp) at base of confining zone = 8,150psi

Safety factor = 0.9 (90%)

Tables 6 and 7 of the AoR CA provide fracture gradients and fracture pressures for the Monterey Formation A1-A2 reservoir, and are replicated below:

Table 6		
Interval	**Fracture Gradient psi/ft**	**Fracture Pressure (psi) at base of Reef Ridge Shale (8,403 ft)**
Monterey Formation A1-A2	0.97	8,150

Table 7		
Injection Pressure Details	**Injection Well 1 357-7R**	**Injection Well 2 355-7R**
Fracture gradient (psi/ft)	0.97	0.97
Maximum injection pressure (90% of fracture pressure) (psi)	7,335	7,335
Elevation corresponding to maximum injection pressure (ft MSL)	8,403	8,403
Elevation at the top of the perforated interval (ft MSL)	8,485	8,462
Calculated maximum injection pressure at the top of the perforated interval (psi)	7,407	7,387
Planned maximum injection pressure / gradient (top of perforations)	4,500 / 0.53	4,500 / 0.53

The maximum injection pressure listed in Table 7 of the AoR CA for injection wells 357-7R and 355-7R does not correspond to the maximum injection pressure in Table 8 of the Narrative or the amended Narrative. Additionally, the proposed injection pressures of 4,500 psi in Table 7 of the AoR CA exceed the proposed average injection pressures of 4,100 psi, listed in Table 8 of the Narrative. It appears that, regardless of the discrepancy in maximum injection pressures, CTV proposes to operate at an injection pressure of 4,100 – 4,500 psi, well below 90% of the injection zone fracture pressure. However, the proposed injection pressures will need to be confirmed as being below 90% of the fracture pressure at the top of the perforations (i.e., within the Monterey Formation injection zone), and the discrepancy in maximum injection pressures will need to be resolved.

CTV states in the AoR CA that their current Class II UIC permit mandates a maximum operating pressure gradient of 0.80 psi/ft unless additional testing indicates a higher gradient. It appears that CTV conducted a test(s) to obtain a higher fracture gradient, 0.9 psi/ft, as seen in Table 6 of the AoR CA, above. However, these tests are not described in the application and will need to be provided for validation of the fracture pressure of the injection and confining zones and the corresponding maximum injection pressures. A question for the applicant regarding this topic is included in the AoR CA Evaluation.

Questions/Requests for the applicant:

- *Please provide separate stand-alone versions of Attachment A for Well 357-7R and Well 355-7R that describe operating conditions. The attachments should include the following: injection well operating conditions (e.g., a tabular description of surface and bottomhole maximum injection pressures, annulus pressure, annulus pressure/tubing differential, and the maximum CO_2 injection rate); how the maximum injection pressure was determined; a description of routine shutdown procedures; and tables summarizing reporting of well and project-related monitoring. The applicant provided stand-alone versions of the operating conditions for Wells 357-7R and 355-7R. Each attachment contains a tabular description of surface and downhole minimum and maximum injection pressures, annulus pressure, and the maximum CO_2 injection rate. The*

annulus pressure/tubing differential was not included on the tables, but CTV referenced the pressure differential will meet the requirements of 40 CFR 146.88 (c) in the Annulus Pressure. EPA recommends that this information be included on the table. CTV also described the routine well shutdown procedures, but did not describe the reporting of monitoring data.

Follow-up Requests for the Applicant:

- ***Please include tables summarizing reporting of well and project-related monitoring. A template with this information, called "Summary of Requirements Template," is available at https://www.epa.gov/uic/class-vi-permit-application-templates.***
- ***Please include the annulus pressure/tubing differential on Table 1 for each well.***

Maximum CO_2 Injection Rate

The applicant proposes a daily CO_2 injection rate of 648 to 1,917 tons per day, which equates to 236,520 to 699,705 tons/year (or 3.5 – 10.5 million tons over the planned 15-year injection phase of the project) as seen in Table 5 of the AoR CA and excerpted below. However, the applicant notes in the Narrative that the storage capacity of the Monterey Formation A1-A2 reservoir is approximately 8 – 10 million tonnes of CO_2 based on computational modeling results. The maximum storage capacity of 10 million tonnes of CO_2 is slightly less than the projected maximum volume of 10.5 million tonnes of CO_2 based on daily injection rates as seen in Table 5 below (assuming injection activities will occur 365 days per year). Based on an evaluation of the AoR delineation modeling and geologic site characterization, it appears that the injection and confining zones are appropriately characterized; however, the range of proposed daily injection rates allow for the exceedance of the modeled storage capacity. The applicant should reconcile this inconsistency and provide an updated range of daily CO_2 injection rates that satisfies the modeled CO_2 storage capacity. See the AoR CA evaluation report for additional discussion.

Table 5. Operating details.

Operating Information	Injection Well 1 357-7R	Injection Well 2 355-7R
Location (global coordinates) X Y	 35.32802963 -119.5449982	 35.33139038 -119.5441437
Model coordinates (ft) X Y	 6,100,956.63 2,308,944.30	 6,101,103 2,310,474
No. of perforated intervals	7	4
Perforated interval (ft MSL) Z top Z bottom	 7,728 8,010	 7,774 7,949
Wellbore diameter (in.)	7	7
Planned injection period Start End	 02/01/2024 04/01/2039	 02/01/2024 04/01/2039
Injection duration (years)	15	15

Injection rate (t/day)*	648 – 1,917	648 – 1,917

*If planned injection rates change year to year, add rows to reflect this difference, and include an average injection rate per year (or interval if applicable).

In the Testing and Monitoring Plan (pg. 5), CTV states that the volume of CO_2 injected into the Monterey Formation A1-A2 Sands will be calculated from the injection flow rate and CO_2 density, and that density will be determined from the Massachusetts Institute of Technology's CO_2 Thermophysical Calculator (https://sequestration.mit.edu/tools/index.html). However, upon investigation of the online calculator, it appears to no longer be operational. The applicant should provide another method by which the CO_2 density will be calculated.

Questions/Requests for the applicant:

- *Please include a description of standard operating procedures to ensure that the maximum daily injection rate will not be exceeded.*
  CTV updated the Operating Procedures for Wells 355-7R and 357-7R to discuss standard operating procedures to ensure that the maximum daily injection rate will not be exceeded. CTV explained that a threshold of 10% over these values will be used to configure the automation and alarms, which equates to 16.5 million cubic feet per day and 4,300 psi. If either threshold is achieved or exceeded, alarms will indicate there is an issue and a response appropriate to the event will be taken. It is unclear how setting the alarm threshold at 10% above the permit limit will avoid a violation of the permit or potential USDW endangerment.
- *Please update the daily CO_2 injection volumes in Table 5 of the AoR CA to ensure they are consistent with the modeled cumulative injection volumes of 8 – 10 million tonnes of CO_2 over 15 years.*
  CTV changed the daily CO_2 injection rate of 648 – 1,917 tonnes/day on Table 5 of the AOR CA to 530 – 794 tonnes/day. This reflects the cumulative injection volume between 8 – 10 million tonnes of CO_2 over 15 years. This response is acceptable, pending resolution of the injection duration (in EPA's follow up questions on the AOR CA).

Follow-up Requests for the Applicant:

- ***The alarm threshold should be set at 90% of the permit's injection pressure limit to avoid a violation of the permit and to ensure protection of USDWs. Please revise the threshold limit.***

Automated Shutdown System

The applicant notes in Attachment F, the Emergency and Remedial Response Plan, that the automatic shutdown devices are activated if wellhead pressure exceeds the specified shutdown pressure listed in the permit, or if the annulus pressure indicates a loss of external or internal well containment. However, standard operating procedures that support the automated shutdown system are not provided.

Questions/Requests for the applicant:

- *Please include standard operating procedures to support the automated shutdown system.* *CTV updated the Operating Procedures for Wells 355-7R and 357-7R to include a subsection on the Automated Shutdown System. CTV discusses that data will be collected in an automated system and monitored by a control system, and if an established operating threshold is seen or exceeded, the software will issue visual, audible, and digital alerts and/or begin with an unload procedure and transition into the shutdown process for appropriate equipment until it is understood why the thresholds were achieved and what corrective measures must be implemented. As CTV describes, they will share information about the monitoring system with EPA when it is established (it is expected that these will be included in well specifications provided later in the permitting process). This update addresses the comment and is acceptable at this point.*